PB-240 231

CRYSTAL LAKE, MONTCALM COUNTY, MICHIGAN

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center, Corvallis, Oregon
National Environmental Research Center, Las Vegas, Nevada
Michigan National Guard
Michigan Department of Natural Resources

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
eutrophication lakes nutrients phosphorus nitrogen loading		05B 05C

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REPORT
ON
CRYSTAL LAKE
MONTCALM COUNTY
MICHIGAN

EPA REGION V

WORKING PAPER No. 191

WITH THE COOPERATION OF THE

MICHIGAN DEPARTMENT OF NATURAL RESOURCES

AND THE

MICHIGAN NATIONAL GUARD

FEBRUARY, 1975

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Michigan Department of Natural Resources for professional involvement and to the Michigan National Guard for conducting the tributary sampling phase of the Survey.

A. Gene Gazlay, former Director, and David H. Jenkins, Acting Director, Michigan Department of Natural Resources; and Carlos Fetterolf, Chief Environmental Scientist, and Dennis Tierney, Aquatic Biologist, Bureau of Water Management, Department of Natural Resources, provided invaluable lake documentation and counsel during the course of the Survey. John Vogt, Chief of the Bureau of Environmental Health, Michigan Department of Public Health, and his staff were most helpful in identfying point sources and soliciting municipal participation in the Survey.

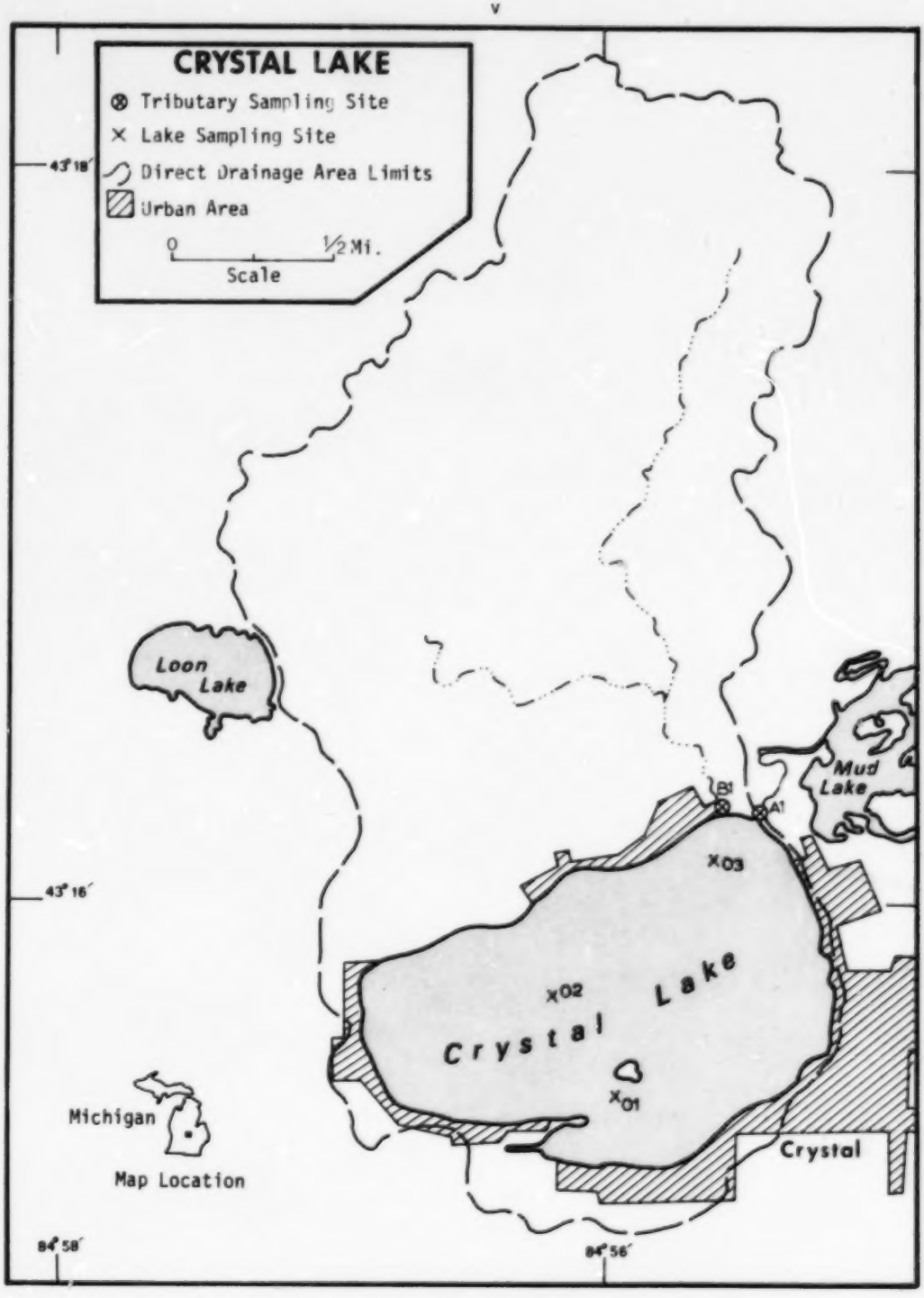
Major General Clarence A. Schnipke (Retired), then the Adjutant General of Michigan, and Project Officer Colonel Albert W. Lesky, who directed the volunteer efforts of the Michigan National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MICHIGAN

LAKE NAME	COUNTY
Allegan Res.	Allegan
Barton	Kalamazoo
Belleville	Wayne
Betsie	Benzie
Brighton	Livingston
Caro Res.	Tuscola
Charlevoix	Charlevoix
Chemung	Livingston
Constantine Res.	St. Joseph
Crystal	Montcalm
Deer	Marquette
Ford	Washtenaw
Fremont	Newago
Higgins	Roscommon
Holloway Res.	Genesee, Lapeer
Houghton	Roscommon
Jordon	Ionia, Barry
Kent	Oakland
Long	St. Joseph
Macatawa	Ottawa
Manistee	Manistee
Mona	Muskegon
Muskegon	Muskegon
Pentwater	Oceana
Pere Marquette	Mason
Portage	Houghton
Randall	Branch
Rogers Pond	Mecosta
Ross	Gladwin
St. Louis Res.	Gratiot
Sanford	Midland
Strawberry	Livingston
Thompson	Livingston
Thornapple	Barry
Union	Branch
White	Muskegon


CRYSTAL LAKE
Tributary Sampling Site
Lake Sampling Site
Direct Drainage Area Limits
Urban Area
0
½ Mi.
Scale
43° 18'
43° 16'
84° 58'
84° 56'
Loon Lake
Mud Lake
B1
A1
X03
X02
X01
Crystal Lake
Crystal
Michigan
Map Location

CRYSTAL LAKE

STORET NO. 2694

I. CONCLUSIONS

A. Trophic Condition:

Survey data show that Crystal Lake is oligotrophic. Of the 35 Michigan lakes sampled in the fall of 1972 when essentially all were well-mixed, three had less mean total phosphorus, two had less mean total dissolved phosphorus, and three had less mean inorganic nitrogen; of all 41 Michigan lakes sampled, only two lakes had less mean chlorophyll a, and three had a greater mean Secchi disc transparency*.

B. Rate-Limiting Nutrient:

Phosphorus was determined to be the limiting nutrient based on the results of the algal assay. The lake data also indicate that phosphorus was the limiting nutrient during all sampling periods (N/P ratios were greater than 14/1).

C. Nutrient Controllability:

1. Point sources--During the sampling year, Crystal Lake received a total phosphorus load at a rate less than that proposed by Vollenweider (in press) as "permissible"; i.e., an oligotrophic rate (see page 11). Of that load, septic tanks are estimated to have contributed about 16% (there are no other

* See Appendix A.

known point sources). However, a shoreline survey would be needed to determine the actual contributions from these sources.

While the present phosphorus loading rate is quite low, every effort should be made to reduce all phosphorus inputs to the lowest practicable level to protect the existing high quality of Crystal Lake.

2. Non-point sources--The mean annual contribution from non-point sources was estimated to be almost 85% of the total phosphorus load reaching Crystal Lake.

The phosphorus export of the unnamed stream (B-1) does not appear to be excessive (see page 11) and is comparable to the exports of other Michigan streams sampled.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry†:

1. Surface area: 724 acres.
2. Mean depth: 13.9 feet.
3. Maximum depth: 70 feet.
4. Volume: 10,064 acre-feet.
5. Mean hydraulic retention time: 3.3 years.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area*	Mean flow*
Unnamed Stream (B-1)	3.8 mi^2	2.9 cfs
Minor tributaries & immediate drainage -	0.7 mi^2	1.3 cfs
Totals	4.5 mi^2	4.2 cfs

2. Outlet -

Unnamed Stream (A-1)	5.6 mi^2**	4.2 cfs

C. Precipitation***:

1. Year of sampling: 34.8 inches.
2. Mean annual: 28.3 inches.

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† MI Cons. Dept. lake inventory map (1941); mean depth by random-dot method.

* Drainage areas are accurate within ±5%; mean daily flows for 74% of the sampling sites are accurate within ±25% and the remaining sites up to ±40%; and mean monthly flows, normalized mean monthly flows, and mean annual flows are slightly more accurate than mean daily flows.

** Includes area of lake.

*** See Working Paper No. 1, "Survey Methods, 1972".

III. LAKE WATER QUALITY SUMMARY

Crystal Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the lake (two in November) and from a number of depths at each station (see map, page v). During each visit, a single depth-integrated (15 feet or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the second visit, a single five-gallon depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 19 feet at station 1, 37 feet at station 2, and 7 feet at station 3.

The results obtained are presented in full in Appendix C, and the data for the fall sampling period, when the lake was essentially well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix C.

A. Physical and chemical characteristics:

Parameter	Minimum	Mean	Median	Maximum
		FALL VALUES (11/14/72)		
Temperature (Cent.)	5.4	5.6	5.7	5.7
Dissolved oxygen (mg/l)	10.8	11.1	11.2	11.4
Conductivity (μmhos)	310	327	330	335
pH (units)	8.2	8.2	8.2	8.2
Alkalinity (mg/l)	126	128	128	129
Total P (mg/l)	0.008	0.009	0.009	0.010
Dissolved P (mg/l)	0.005	0.006	0.006	0.007
$NO_2 + NO_3$ (mg/l)	0.060	0.064	0.060	0.080
Ammonia (mg/l)	0.090	0.100	0.100	0.120
		ALL VALUES		
Secchi disc (inches)	48	120	114	180

B. Biological characteristics:

1. Phytoplankton* -

Sampling Date	Dominant Genera	Number per ml
09/17/72	1. Microcystis	944
	2. Dinobryon	217
	3. Merismopedia	112
	4. Aphanocapsa	61
	5. Chroococcus	51
	Other genera	170
	Total	1,555
11/14/72	1. Dinobryon	1,394
	2. Flagellates	923
	3. Asterionella	433
	4. Achnanthes	226
	5. Navicula	132
	Other genera	922
	Total	4,030

* The June sample was lost in shipment.

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (µg/l)
06/15/72	01	5.2
	02	3.7
09/17/72	01	2.0
	02	3.2
	03	3.3
11/14/72	01	1.9
	02	1.6

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.007	0.107	0.1
0.010 P	0.017	0.107	3.0
0.020 P	0.027	0.107	3.5
0.050 P	0.057	0.107	3.4
0.050 P + 5.0 N	0.057	5.107	19.1
0.050 P + 10.0 N	0.057	10.107	17.6
10.0 N	0.007	10.107	0.1

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity was low at the time the sample was collected. The increase in yield with the addition of phosphorus (to about 0.020 mg/l) indicates phosphorus limitation. Note the lack of yield response when only nitrogen was added.

The lake data indicate phosphorus limitation; i.e., N/P ratios were 14/1 or higher, and phosphorus limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Michigan National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of January, March, and May when two samples were collected. Sampling was begun in October, 1972, and was completed in October, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Michigan District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in lbs/mi^2/year, at station B-1 and multiplying the means by the ZZ area in mi^2.

A. Waste Sources:

1. Known municipal - None
2. Known industrial - None

* See Working Paper No. 1.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
Unnamed Stream (B-1)	230	51.1
b. Minor tributaries & immediate drainage (non-point load) -	40	8.9
c. Known municipal STP's - None	-	-
d. Septic tanks* -	70	15.6
e. Known industrial - None	-	-
f. Direct precipitation** -	110	24.4
Total	450	100.0

2. Outputs -

Lake outlet - Unnamed Stream (A-1) 120

3. Net annual P accumulation - 330 pounds

* Estimate based on 106 shoreline dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/ yr	% of total
a. Tributaries (non-point load) -		
Unnamed Stream (B-1)	8,100	42.5
b. Minor tributaries & immediate drainage (non-point load) -	1,490	7.8
c. Known municipal STP's - None	-	-
d. Septic tanks* -	2,490	13.1
e. Known industrial - None	-	-
f. Direct precipitation** -	6,980	36.6
Total	19,060	100.0

2. Outputs -

Lake outlet - Unnamed Stream (A-1)	10,820

3. Net annual N accumulation - 8,240 pounds

* Estimated based on 106 shoreline dwellings; see Working Paper No. 1.
** See Working Paper No. 1.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Unnamed Stream (B-1)	61	2,132

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving water would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with very short retention times.

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	0.6	0.5	25.3	11.4
grams/m^2/yr	0.07	0.05	3.0	1.3

Vollenweider loading rates for phosphorus (g/m^2/yr) based on mean depth and mean hydraulic retention time of Crystal Lake:

"Dangerous" (eutrophic rate)	0.24
"Permissible" (oligotrophic rate)	0.12

V. LITERATURE REVIEWED

Fetterolf, Carlos, 1974. Personal communication (lake morphometry). Dept. Nat. Resources, Lansing.

Miller, J. B., and T. Thompson, 1974. Compilation of data for Michigan lakes. U.S. Geological Survey and Michigan Dept. Nat. Resources, Lansing.

Vollenweider, Richard A. (in press). Input-output models. Schweiz. Z. Hydrol.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: SQU-MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15-MIN DO
2640	HOLLOWAY RESERVOIR	0.062	0.043	1.461	439.375	10.676	9.200
2641	CARO RESERVOIR	0.117	0.022	3.835	473.000	11.967	9.500
2642	BOARDMAN HYDRO POND	0.006	0.005	0.358	363.500	1.267	6.600
2603	ALLEGAN LAKE	0.123	0.057	1.168	470.222	20.311	12.600
2606	BARTON LAKE	0.121	0.086	1.489	458.167	27.800	14.850
2609	BELLEVILLE LAKE	0.118	0.048	1.420	465.250	28.262	8.200
2610	BETSIE LAKE	0.025	0.008	0.273	461.667	4.567	7.400
2613	BRIGHTON LAKE	0.109	0.073	1.015	458.000	44.233	7.500
2617	LAKE CHARLEVOIX	0.007	0.006	0.230	351.250	3.008	9.240
2618	LAKE CHEMUNG	0.044	0.014	0.132	484.333	13.483	14.800
2621	CONSTANTINE RESERVOIR	0.027	0.008	0.918	456.167	39.317	7.500
2629	FORD LAKE	0.185	0.058	1.536	456.167	14.733	14.000
2631	FREMONT LAKE	0.372	0.342	1.406	441.667	28.500	14.800
2640	JORDAN LAKE	0.180	0.144	1.498	427.667	20.517	14.900
2643	KENT LAKE	0.040	0.015	0.417	455.000	33.944	13.000
2648	LAKE MACATAWA	0.197	0.120	2.358	477.600	25.600	12.200
2649	MANISTEE LAKE	0.018	0.010	0.304	491.333	6.317	11.340
2659	MUSKEGON LAKE	0.047	0.043	0.469	436.444	9.511	14.900
2665	PENTWATER LAKE	0.027	0.017	0.496	430.667	16.083	14.800
2671	RANDALL LAKE	0.244	0.183	0.818	497.333	27.217	8.020
2672	ROGERS POND	0.026	0.015	0.183	435.500	6.133	9.600
2673	RUSS RESERVOIR	0.034	0.021	0.460	465.333	10.383	8.200
2674	SANFORD LAKE	0.016	0.008	0.307	458.750	13.791	8.300
2683	THORNAPPLE LAKE	0.042	0.032	1.737	442.833	14.650	10.800
2685	UNION LAKE	0.083	0.064	1.252	455.500	15.667	8.200
2688	WHITE LAKE	0.027	0.019	0.367	417.778	9.211	13.400
2691	MUNA LAKE	0.387	0.241	0.963	451.667	27.783	14.100
2692	LONG LAKE	0.163	0.148	0.749	418.400	10.367	13.600

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	---------FALL VALUES--------- MEAN TOTAL P	MEAN DISS P	MEAN INORG N	----------ALL VALUES---------- 500- MEAN SEC	MEAN CHLORA	15- MIN DO
2693	ST LOUIS RESERVOIR	0.134	0.093	1.227	462.667	5.583	8.420
2694	CRYSTAL LAKE	0.009	0.006	0.164	380.000	2.986	13.000
2695	HIGGINS LAKE	0.007	0.005	0.058	268.500	1.043	9.400
2696	HOUGHTON LAKE	0.018	0.008	0.136	420.833	9.217	8.200
2697	THOMPSON LAKE	0.043	0.029	0.436	407.889	11.967	14.800
2698	PERE MARQUETTE LAKE	0.032	0.024	0.346	448.667	11.833	8.600
2699	STRAWBERRY LAKE	0.069	0.050	0.567	419.800	11.117	13.600

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	ALL VALUES MEAN TOTAL P	ALL VALUES MEAN DISS P	ALL VALUES MEAN INORG N	ALL VALUES SDD= MEAN SEC	ALL VALUES MEAN CHLUMA	ALL VALUES 15= MIN DO	INDEX NO
2640	HULLUWAY RESERVOIR	46 (161	43 (151	17 (61	57 (201	60 (211	63 (221	266
2641	CARO RESERVOIR	29 (131	54 (191	0 (01	3 (11	49 (171	54 (191	189
2642	WAHOMAN HYDRO POND	97 (341	97 (341	69 (241	91 (321	94 (331	97 (341	949
2643	ALLEGAN LAKE	20 (71	31 (111	31 (111	6 (21	29 (101	40 (141	197
2646	HANTUN LAKE	23 (81	20 (71	14 (51	29 (91	14 (51	3 (11	103
2649	BELLEVILLE LAKE	26 (91	37 (131	20 (71	11 (41	11 (41	79 (261	184
2650	BETSIE LAKE	77 (271	77 (271	80 (281	17 (61	86 (301	94 (331	431
2653	BRIGHTON LAKE	31 (111	23 (81	34 (121	34 (121	0 (01	90 (311	212
2657	LAKE CHARLEVOIX	91 (321	91 (321	83 (291	94 (331	89 (311	60 (211	508
2658	LAKE CHEMUNG	49 (171	71 (251	94 (331	86 (301	46 (161	11 (21	357
2661	CONSTANTINE RESERVOIR	71 (251	83 (291	40 (141	29 (91	3 (11	90 (311	319
2669	FORD LAKE	34 (121	29 (101	11 (41	29 (91	37 (131	23 (81	163
2671	FREMONT LAKE	0 (01	0 (01	23 (81	54 (191	9 (31	11 (21	97
2680	JORDAN LAKE	11 (41	11 (41	6 (21	69 (241	26 (91	0 (01	123
2683	KENT LAKE	57 (201	69 (241	63 (221	40 (141	6 (21	36 (121	271
2688	LAKE MACATAWA	9 (31	14 (51	3 (11	0 (01	23 (81	43 (151	92
2689	MANISTEE LAKE	80 (281	74 (261	77 (271	46 (161	80 (281	46 (161	403
2690	MUSKEGON LAKE	37 (131	40 (141	54 (191	60 (211	69 (241	11 (21	271
2695	PENTWATER LAKE	69 (241	63 (221	51 (181	66 (231	31 (111	11 (21	241
2671	RANDALL LAKE	6 (21	6 (21	43 (151	23 (81	20 (71	86 (301	184
2672	ROGERS POND	74 (261	66 (231	86 (301	63 (221	77 (271	51 (181	417
2673	RUSS RESERVOIR	60 (211	57 (201	57 (201	9 (31	63 (221	74 (261	323
2674	SANFORD LAKE	86 (301	80 (281	74 (261	20 (71	43 (151	71 (251	374
2683	THORNAPPLE LAKE	54 (191	46 (161	9 (31	51 (181	40 (141	49 (171	249
2685	UNION LAKE	40 (141	26 (91	26 (91	37 (131	34 (121	79 (261	242
2688	WHITE LAKE	66 (231	60 (211	66 (231	80 (281	74 (261	31 (111	377
2691	WUNA LAKE	3 (11	3 (11	37 (131	43 (151	17 (61	20 (71	123
2692	LONG LAKE	14 (51	9 (31	46 (161	77 (271	66 (231	27 (91	239

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	FALL VALUES: MEAN TOTAL P	FALL VALUES: MEAN DISS P	FALL VALUES: MEAN INORG N	ALL VALUES: 500-MEAN SEC	ALL VALUES: MEAN CHLORA	ALL VALUES: 15-MIN DO	INDEX NO
2693	ST LOUIS RESERVOIR	17 (6)	17 (6)	29 (10)	14 (5)	83 (29)	69 (24)	229
2694	CRYSTAL LAKE	89 (31)	89 (31)	89 (31)	89 (31)	91 (32)	36 (12)	483
2695	HIGGINS LAKE	94 (33)	94 (33)	97 (34)	97 (34)	97 (34)	57 (20)	536
2696	HOUGHTON LAKE	83 (29)	86 (30)	91 (32)	71 (25)	71 (25)	79 (26)	481
2697	THOMPSON LAKE	51 (18)	49 (17)	60 (21)	83 (29)	51 (18)	11 (2)	305
2698	PERE MARQUETTE LAKE	63 (22)	51 (18)	71 (25)	49 (17)	54 (19)	66 (23)	354
2699	STRAWBERRY LAKE	43 (15)	34 (12)	49 (17)	74 (26)	57 (20)	27 (9)	284

APPENDIX B

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MICHIGAN 2/3/75

LAKE CODE 2694 CRYSTAL LAKE

TOTAL DRAINAGE AREA OF LAKE(SQ MI) 5.58

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2694A1	5.58	3.88	4.28	6.56	7.87	5.66	3.48	2.68	2.54	2.65	3.12	3.86	4.05	4.22
2694B1	3.81	2.65	2.91	4.48	5.38	3.87	2.37	1.83	1.73	1.81	2.13	2.63	2.76	2.88
2694ZZ	1.77	1.23	1.35	2.08	2.50	1.80	1.10	0.85	0.80	0.84	0.99	1.22	1.28	1.34

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 5.58
SUM OF SUB-DRAINAGE AREAS = 5.58
TOTAL FLOW IN = 50.59
TOTAL FLOW OUT = 50.63

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2694A1	10	72	5.00	28	9.20				
	11	72	6.10						
	12	72	13.00	1	4.90				
	1	73	9.50	19	21.00	30	5.10		
	2	73	5.80	19	4.90				
	3	73	10.00	20	12.00	28	8.60		
	4	73	9.43	26	8.20				
	5	73	9.30	24	6.70	31	11.00		
	6	73	7.70	26	5.40				
	7	73	4.80	27	4.10				
	8	73	4.20	31	2.80				
	9	73	3.10						
	10	73	3.30	15	4.00				
2694B1	10	72	3.40	28	6.20				
	11	72	4.10						
	12	72	8.90	1	3.40				
	1	73	6.50	19	14.00	30	3.50		
	2	73	3.90	19	3.40				
	3	73	7.10	20	7.80	28	5.80		
	4	73	6.40	26	5.60				
	5	73	6.30	24	4.50	31	7.70		
	6	73	5.20	26	3.70				
	7	73	3.20	27	2.80				
	8	73	2.40	31	1.90				
	9	73	2.10						
	10	73	2.20	15	2.80				

TRIBUTARY FLOW INFORMATION FOR MICHIGAN

LAKE CODE 2694 CRYSTAL LAKE

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
269422	10	72	1.60						
	11	72	1.90						
	12	72	4.10						
	1	73	3.30						
	2	73	1.40						
	3	73	3.30						
	4	73	2.70						
	5	73	2.60						
	6	73	2.40						
	7	73	1.50						
	8	73	1.30						
	9	73	1.00						
	10	73	1.00						

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APPENDIX C

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 75/02/14

269401
43 15 30.0 084 56 00.0
CRYSTAL LAKE
26 MICHIGAN

11EPALES
4

2111202
0018 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/15	07	15 0000	20.0	8.0	168	330	8.42	143	0.020	0.030	0.007	0.006
	07	15 0015	17.7	9.4		340	8.33	141	0.020	0.040	0.009	0.005
72/09/17	12	40 0000			132	320	8.45	121	0.060	0.120	0.011	0.008
	12	40 0004	20.4	8.1		320	8.50	122	0.070	0.120	0.007	0.007
	12	40 0015	19.9	8.2		315	8.50	120	0.060	0.130	0.007	0.006
	12	40 0019	19.9	8.2		315	8.45	119	0.060	0.110	0.009	0.007
72/11/14	09	00 0000			100	330	8.20	127	0.070	0.110	0.009	0.006
	09	00 0004	5.4	10.9		310	8.20	127	0.060	0.100	0.010	0.007
	09	00 0010	5.4	11.2		325	8.20	128	0.060	0.090	0.010	0.006

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/15	07	15 0000	5.2J
72/09/17	12	40 0000	2.0J
72/11/14	09	00 0000	1.9J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

269402
43 15 43.0 084 56 13.0
CRYSTAL LAKE
26 MICHIGAN

11EPALES
3

2111202
0037 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/15	07	40 0000	20.1	7.9	180	330	8.45	141	0.020	0.040	0.008	0.006
	07	40 0015	18.8	8.0		345	8.22	141	0.030	0.060	0.007	0.005
	07	40 0037	11.1	2.0		365	7.52	162	0.090	0.110	0.011	0.008
72/09/17	13	05 0000			120	320	6.92	121	0.080	0.120	0.009	0.008
	13	05 0004	20.4	9.7		320	8.50	122	0.070	0.090	0.009	0.007
	13	05 0015	20.0	8.3		320	8.40	121	0.070	0.120	0.008	0.007
	13	05 0023	19.9	6.4		320	8.40	129	0.060	0.190	0.008	0.006
	13	05 0031	18.0	5.1		340	7.90	130	0.060	0.190	0.009	0.007
72/11/14	09	20 0000			104	335	8.20	129	0.060	0.090	0.008	0.006
	09	20 0004	5.7	11.2		330	8.20	128	0.060	0.090	0.009	0.005
	09	20 0015	5.7	10.8		325	8.20	128	0.080	0.120	0.009	0.007
	09	20 0036	5.7	11.4		335	8.20	126	0.060	0.100	0.009	0.005

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/06/15	07	40 0000	3.7J
72/09/17	13	05 0000	3.2J
72/11/14	09	20 0000	1.6J

J VALUE KNOWN TO BE IN ERROR

STORET RETRIEVAL DATE 75/02/04

269403
43 16 00.0 084 55 30.0
CRYSTAL LAKE
26 MICHIGAN

11EPALES
4

2111202
0005 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/06/15	08 05 0000		20.0	8.0	48	330	8.45	142	0.020	0.040	0.008	0.008
72/09/17	13 30 0000				108	320	8.50	122	0.060	0.110	0.009	0.008
	13 30 0004		21.6	8.6		320	8.50	121	0.070	0.120	0.013	0.010
	13 30 0007		20.6	8.6		318	8.50	121	0.060	0.090	0.007	0.007

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/09/17	13 30 0000		3.30

J VALUE [illegible]

APPENDIX D

TRIBUTARY DATA

STORET RETRIEVAL DATE 75/02/24

2574A1 L52694A1
43 16 30.0 084 55 30.0
UNNAMED OUTLET CRYSTAL/MUD LK CO
20 7.5 CRYSTAL
U/CRYSTAL LAKE
WALDRON RD BRDG NNE SIDE OFCRYSTAL LAKE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/24	10	00	0.044	2.200	.058	0.005K	0.011
72/12/01	10	20	0.120	2.200	0.140	0.005K	0.011
73/01/19	14	22	0.210	0.800	0.038	0.023	0.046
73/01/30	10	15	0.124	0.740	0.057	0.005K	0.010
73/02/19	12	46	0.134	0.740	0.045	0.005K	0.010
73/03/20	10	25	0.120	0.720	0.044	0.005K	0.010
73/03/28	14	15	0.110	0.760	0.050	0.005K	0.010
73/04/26	12	45	0.044	0.600	0.021	0.005K	0.010
73/05/24	13	40	0.005	1.300	0.031	0.005	0.010
73/05/31	11	32	0.045	1.500	0.052	0.005	0.015
73/06/26	10	15	0.010K	1.500	0.042	0.005	0.015
73/07/27	14	15	0.025	0.490	0.027	0.013	0.020
73/08/31			0.010K	0.700	0.040	0.005	0.015
73/10/15	15	05	0.017	2.000	0.078	0.005K	0.015

K VALUE KNOWN TO BE
LESS THAN INDICATED

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STORET RETRIEVAL DATE 75/02/04

```
 259481          L3259481
43 16 30.0 084 55 30.0
UNNAMED CREEK
26       7.5 CRYSTAL
17CRYSTAL LAKE
SECONDARY RD BRDG .1 MI W OF WALDRON RD
11EPALES                  2111204
4                         0000 FEET  DEPTH
```

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/28	10 05		0.200	0.840	0.058	0.018	0.023
72/12/01	10 30		0.430	1.550	0.054	0.006	0.011
73/01/19	14 25		0.200	0.840	0.039	0.027	0.038
73/03/20	10 15		0.110	0.580	0.026	0.018	0.035
73/03/28	14 10		0.061	1.130	0.154	0.006	0.025
73/04/25	12 00		0.150	1.050	0.044	0.011	0.030
73/05/24	13 35		0.115	1.100	0.066	0.008	0.025
73/05/31	11 25		0.054		0.116	0.015	0.027
73/06/26	10 11		0.110	2.100	0.270	0.026	0.055
73/07/27	14 50		0.110	2.000	0.056	0.033	0.070
73/08/31			0.210	1.150	0.140	0.021	0.030
73/10/15	15 00		0.130	0.450	0.054	0.021	0.030